FOURTH QUARTER 1960
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ENVIRONMENTAL QUARTERLY

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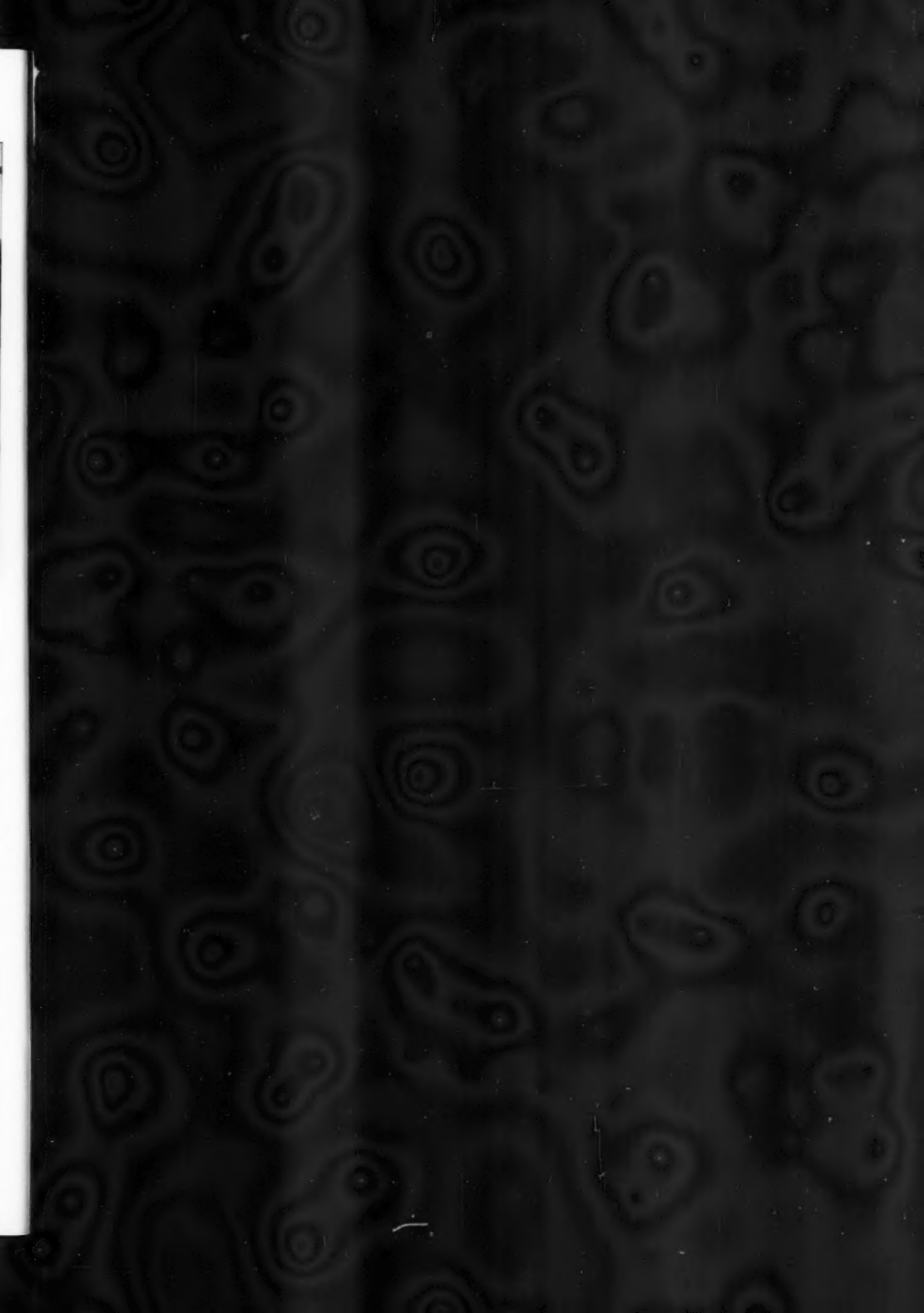

Volume 4, No. 4 Fourth Quarter 1958

ENVIRONMENTAL QUARTERLY

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Laboratory Simulation of Rocket Engine Noise 6

by Merwin T. Anderson & Leonard L. Robinson

After some intense experiments with small reverberant chambers, AVCO engineers applied their findings to full-sized lab chambers for subjecting AF Titan re-entry vehicle components to simulated rocket engine noise.

A Defense of Vibration Instrumentation 30

by George M. Watt

According to the author, some vibration instrumention has been unfairly condemned as inaccurate when the real trouble may be misinterpretation of data presented by the instruments.

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RAY H. MATTINGLEY

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Rigid Dummy Loads For Shock and Vibration Tests 10

by Bruno J. Forsher

For some applications, rigid dummy loads may serve as well during shock testing as electronic packages. Certainly there is important economy in this technique. Environmental Quarterly invites your comments.

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EDITORIAL

This issue of ENVIRONMENTAL QUARTERLY is published solely under the aegis of the Environmental Equipment Institute. From the third quarter 1956 through the third quarter 1958, these words appeared in the magazine's masthead: "Official publication of the Environmental Equipment Institute and the Institute of Environmental Engineers."

Effective this month, the two institutes have formally severed connection, and the *Environmental Quarterly* represents the EEI alone. The Institute of Environmental Engineers has now fulfilled the original dream of the EEI: To originate, foster, and perfect a new engineering society for the advancement of the art in the field of environmental simulation, testing, and research.

Beginning as an idea in 1953, the engineering group took form as the Science Section of the EEI in 1954. In April of 1955, the Science Section held its first annual meeting in Chicago. For this small beginning, the response was overwhelming: 170 scientists and engineers attended. Over 300 attended the next year's meeting. In the summer of 1956, the Science Section became the Institute of Environmental Engineers, Incorporated, but still remained connected with its parent organization for support and financial sustenance. *The IEE Is Born* was the title of an editorial in the July the 1956 issue of *Environmental Quarterly*.

The adolescent is now a man. Today, the IEE stands alone.

We join the entire membership of the Environmental Equipment Institute in wishing the Institute of Environmental Engineers complete success in the many years ahead.

Since it is our policy to present news of all important events in the field of environmental engineering, the pages of *Environmental Quarterly* will continue to carry reports of the activities of the IEE.

Ray H. Mattingley

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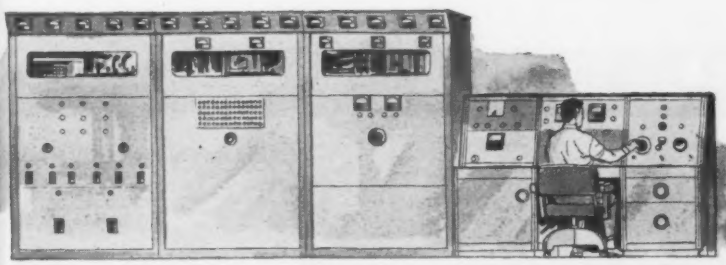

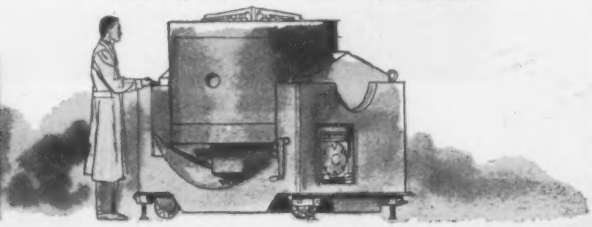

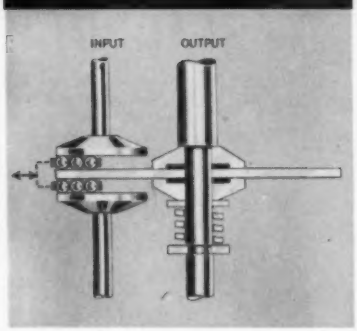

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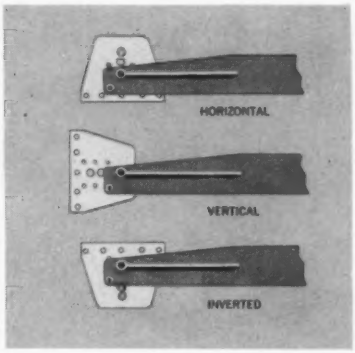

Basket-type mounting platforms, available on Model A-1020 and A-1030, may be oriented from the horizontal to the vertical or to the inverted attitude for multiple-axis testing without demounting the test object. Baskets may be raised or lowered to achieve an optimum dynamic balance and minimum angular deflections when extreme accuracies are required. When the basket is inverted the outside surface of the platform may be used to mount bulky, lightweight packages.

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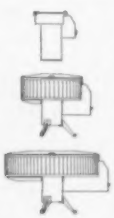
brief performance specifications



Model No.	Diameter	Test Object Weight	Capacity G-pounds	RPM Max.	G-Range Max.	Test Object Dimensions
A-1010	30" table	50 lbs. dead weight	2,500	800	.1 to 200 g's	
A-1020	60" arm	100 lb. dead weight	10,000	600	.1 to 250 g's	12" cube
A-1030	96" arm	100 lb. dead weight	10,000	400	.1 to 175 g's	18" cube

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AVCO ENGINEERS STATE THESE CONCLUSIONS ABOUT REVERBERATION CHAMBERS, AFTER AN INTENSIVE STUDY:

Loudspeakers should be grouped together as closely as possible. Four speakers on one wall of a reverberant room are more effective than one speaker on each of four walls.

Acute angles between adjacent sides of a reverberant room tend to decrease chamber effectiveness.

Parallel surfaces in the chamber, including floor and ceiling, produce predominant frequency components.

Non-parallel-wall chambers are more effective than parallel-wall chambers with diffusion panels.

Significant differences exist in the frequency spectra at different points in the chamber, but in the over-all sound pressure levels are fairly constant throughout.

THE ACOUSTIC NOISE environment produced by rocket engines during launch and powered flight of a guided missile is capable of causing malfunctions in components in the missile. Since extremely high reliability must be obtained for each missile component, acoustic noise environments—as well as mechanical vibration environments—must be simulated in the laboratory to prove that components will not fail during missile flight. Mechanical vibration tests alone are not sufficient. Experience has shown that some components operate properly during mechanical vibrations, but fail when subjected to an acoustic noise environment.

A typical example is a shock-mounted or vibration-isolated component. Shock mounts are basically mechanical filters used to attenuate excitations above the natural frequency of the shock mounts. Components that are isolated from mechanical vibrations are not necessarily isolated from acoustical excitations. Mechanical excitations are transmitted to the component through the shock mounts. Acoustical excitations are transmitted directly to the component; therefore, resonances in the component will be excited at frequencies above the natural frequencies of the shock mounts.

Since it is expensive and impractical to operate rocket engines in the laboratory for acoustic tests, aircraft and missile manufacturers have developed test facilities that are relatively inexpensive to operate. At the AVCO Research and Advanced Development Division, an acoustic testing facility was developed to simulate the internal noise levels and frequency spectra that are experienced in rocket powered guided missiles. The facility, which consists of two progressive wave tubes and a pentagonal reverberant chamber, is used to perform acoustic noise tests on components and systems of the re-entry vehicle for the Air Force Titan ICBM. The progressive wave tubes are 4 inches and 10 inches in diameter, and the reverberant chamber has a volume of 900 cubic feet. Acoustic noise tests on components and small sub-assemblies are performed in the progressive wave tubes, and large assemblies are tested in the reverberant chamber. Electromagnetic loudspeakers were designed and developed by AVCO to provide the low-frequency acoustic excitations, and Altec-Lansing Model 290C loundspeakers are used for mid-range frequencies. The loudspeakers are powered and controlled by amplifiers that are part of available vibration testing equipment in the laboratory.

This facility can:

1. Simulate internal noise environments of rocket powered missiles that are random in amplitude with continuous and broadband frequency spectra.
2. Produce sound-pressure levels of 164 db* and 155 db for testing components with cross-sectional areas of 3 and 20 square inches respectively in progressive wave tubes.

* db as used here is defined as a sound pressure level equal to 20 log $P/P_{ref.}$ where $P_{ref.} = 0.0002$ microbars

Laboratory Simulation of *Rocket Engine Noise*

MERWIN T. ANDERSON & LEONARD L. ROBINSON
AVCO Research and Advanced Development Division

The authors describe an acoustic facility developed for testing components of the re-entry vehicle of the AF Titan ICBM

3. Produce sound-pressure levels of 152 db for testing assemblies as large as 90 cubic feet in volume in the pentagonal reverberant chamber.

6KW Loudspeaker

The transducers for an acoustical testing facility have to be capable of producing random noise at a high sound-pressure level with a frequency spectrum similar to that produced by a high-thrust rocket engine. Flight vehicles have now been instrumented with microphones to determine the sound pressure level and the frequency spectra of the noise environment during the flight of the missile. The results of the analyses of flight and captive test data have revealed that the acoustical noise environment is random in amplitude with a continuous broad-band frequency spectrum. Most of the acoustical energy in the spectrum, however, is concentrated between 50 and 500 cps.

We selected electromagnetic loudspeakers rather than sirens or modulated air flow horns to simulate the rocket engine noise environment because there are electronic amplifiers available in our Environmental Test Laboratories that could be used to drive the loudspeakers. The amplifiers, which are rated at 15 KVA to 70 KVA, are part of the mechanical vibration testing systems in the laboratory. Sirens and modulated air flow horns were disregarded since a high capacity, low pressure air supply would have to be purchased for these types of transducers which would increase the cost of the acoustic testing facility appreciably.

Manufacturers in the United States as well as Great Britain were contacted in an effort to purchase low-frequency loudspeakers. None could supply equipment that would produce the required acoustic power at frequencies below 500 cps. Therefore, a loudspeaker was designed and developed that could be used with the available amplifiers and would produce the desired sound pressure level and frequency spectrum.

A horn-type loudspeaker was designed because the displacement required for a diaphragm to produce acoustical power at low frequencies in this type is much less than for a direct radiating loudspeaker. An electrical analog for a horn-type loudspeaker was studied. It was apparent that the spring constant of the suspension system and the mass of the armature should be as low as possible to increase efficiency at the low frequencies. Although the flux density does not seriously affect the frequency response of a loudspeaker, it should be as high as possible since the force produced with a constant current through the armature winding is directly proportional to the flux density.

Figure 1 is a cutaway drawing of the loudspeaker. The magnetic structure is combined with a device to focus the sound from a diaphragm 12 inches in diameter to a throat 3 inches in diameter. The magnet was designed to provide a flux of approxmitely 20 kilogauss

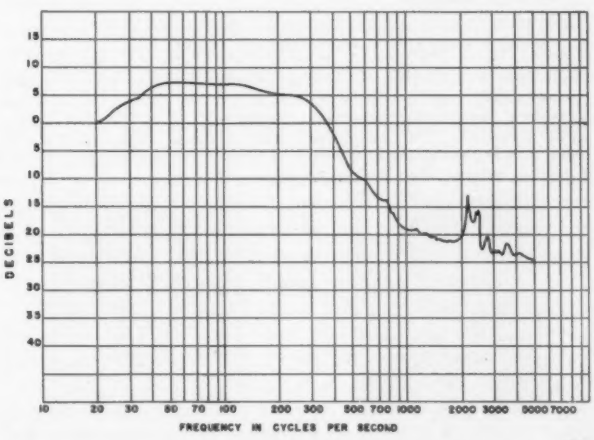


Figure 2. Frequency response of 6KW loudspeaker.

in an annular air gap that is ½ inch wide, 3 inches deep, and 12-5/16 inches in diameter.

Several moving coils were designed and modified to provide high force-to-weight ratios capable of withstanding the mechanical stresses. The moving coils that are being used weigh 5-½ pounds and produce a root mean square force of approximately 1,500 pounds when driven with unclipped random noise for a sustained period.

Several types of suspension systems were designed and tested for the speaker. An ideal suspension has a very low spring constant, adds no weight to the moving coil, and holds the moving coil in the center of the air gap. A bicycle spoke type suspension was found to be satisfactory for normal operation, but transients in the amplifier caused too many failures. At present, the moving coil is suspended by U-shaped beryllium copper springs that are spaced 45° apart. No failures have been experienced with this type of suspension and there is no significant change in the response of the speaker compared with the bicycle spoke suspension.

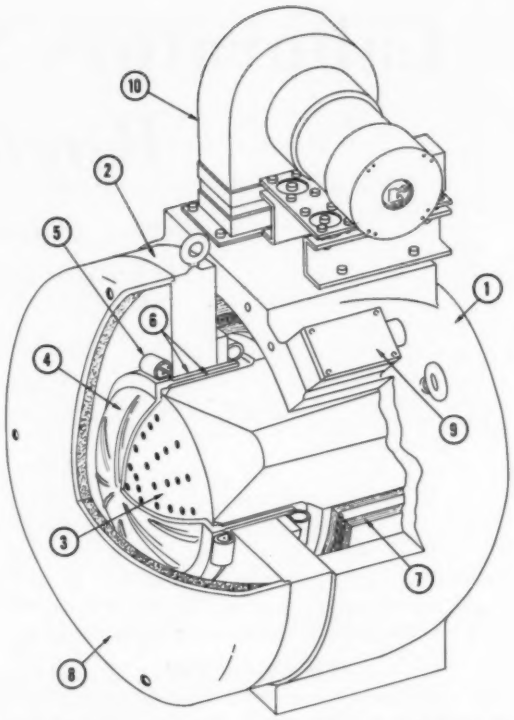
The frequency response of the loudspeaker is shown in Figure 2. For this response curve, the loudspeaker was operating in a progressive wave tube. A constant voltage sinusoidal signal controlled the 15 KVA amplifier that was used to power the speaker. The effective range of the loudspeaker is from 20 to 5000 cps and the response is essentially flat from 35 to 250 cps. The peak in the response at 2,200 to 2,500 cps is the resonant frequency of the diaphragm. By varying the spacing between the diaphragm and the focusing device, the basic response of the loudspeaker can be changed slightly. Extreme variations in the speaker response can be made by driving the amplifier with a shaped frequency spectrum rather than a flat or white spectrum, which was used for the response curve in Figure 2.

Test Facilities

Development tests on parts and components with cross sectional areas of less than 20 square inches are performed in progressive wave tubes powered by the 6KW loudspeaker. In this type of facility, the acoustic energy or sound wave progresses down a long tube and is absorbed at the end. The largest tube in our laboratory is 10 inches in diameter. If the loudspeaker is driven with random white noise from 20 to 5,000 cps, a sound pressure level of 155 db can be produced in the 10-inch tube. For short periods, eight kilowatts can be used to drive the loudspeaker at higher levels. Smaller components with cross-sectional areas of less than 3 square inches are subjected to acoustic noise environments in a 4-inch diameter progressive wave tube. Here a random noise sound pressure level of 164 db is produced with the 6KW loudspeaker, and levels of approximately 170 db can be produced at discrete frequencies. Both the 4-inch and 10-inch diameter tubes are 12 feet long. The frequency spectra with random noise for these facilities is essentially the same as the response curve shown in Figure 2.

The progressive wave tubes were selected for testing small parts because the noise in this type of facility is well defined with either sinusoidal or random excitation. It is an excellent facility for performing development tests since the angle of incidence of the noise can be specified for one or more axes of the component. Progressive-wave tubes are impractical for testing large specimens, though, because of the large amount of power required to produce the desired noise levels. Also it is much easier to excite the cross modes in larger tubes—thereby having standing waves along the diameter of the tube.

Large specimens are tested in enclosed or reverberant



1. HOUSING
2. FRONT PLATE
3. FOCUSING DEVICE
4. MOVING COIL
5. MOUNTING SPRINGS
6. ANNULAR GAPS
7. FIELD COIL
8. SHIELD
9. JUNCTION BOX
10. BLOWER

Figure 1. 6KW loudspeaker.

MERWIN T. ANDERSON. BME: Rensselaer Polytechnic, 1952; MS: Oklahoma A & M, 1953. AVCO R and A D Div., Chief of Test Project B.

LEONARD L. ROBINSON. BSEE: Univ. of Texas, 1956. AVCO R and A D Div., Associate Engineer.

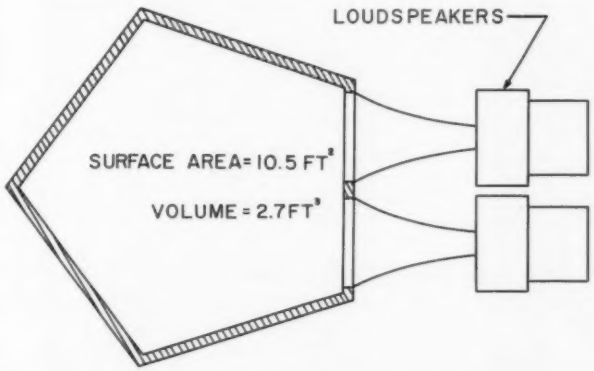
Both Anderson and Robinson are engaged in product development and test and evaluation of components and systems for re-entry vehicles of ICBM.

chambers. These are more efficient than progressive wave tubes with respect to sound pressure levels produced for a specific amount of power. Since many of the internal parts of the missile will be mounted in an enclosed compartment bounded by the missile external structure and the bulkheads, the internal acoustic noise environment will be similar to the noise produced in a reverberant chamber.

Study of Small Chambers

To determine a suitable configuration for the reverberant chambers for our laboratory, an investigation was conducted with small chambers. Two of the configurations investigated are shown in Figures 3 and 4 along with frequency spectra for each configuration. The frequency spectra are one-third octave band responses. Note that white noise or a flat single-frequency response would be represented as a straight line with a slope of 3 db/octave. It is apparent from the frequency spectra, that the sound pressure level is more uniform and at a higher level in the pentagonal chamber even though this configuration has a larger surface area and a larger volume. For the two examples presented, four Altec Model 290C loudspeakers were used as the noise source. The frequency response of these speakers is essentially flat from 400 to 4,000 cps.

Square and rectangular chambers were also investigated. For all four configurations, tests were performed with the speakers mounted on only one side, more than one side, and in some instances with the loudspeakers covering all the available area of the chamber. Tests were also performed with panels and diffusing blocks attached to the interior of the rectangular chambers in an attempt to obtain a more uniform noise spectra in the chamber.



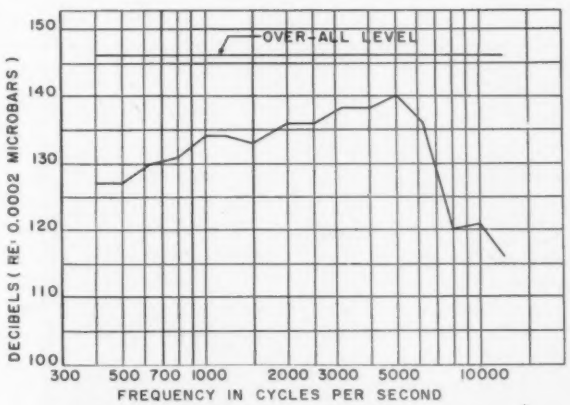
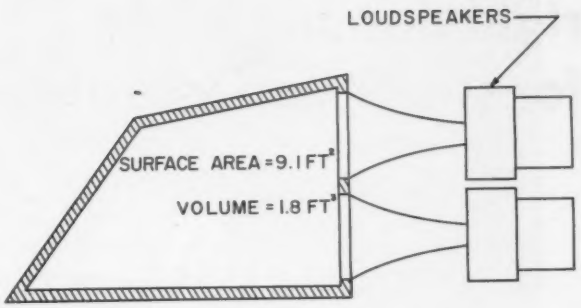


Figure 3. Pentagonal reverberant chamber.



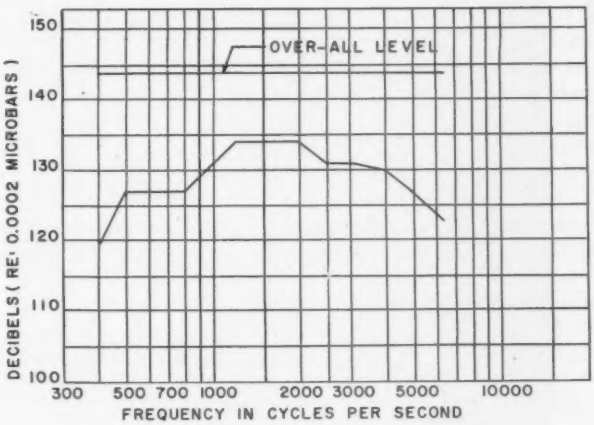


Figure 4. Nonparallel wall chamber.

Results of this small-chamber investigation are summed up in the tabulation at the top of page 6. Making use of these findings, a 900 cubic foot pentagon chamber was constructed. A cutaway drawing of the chamber is shown in Figure 5. Four of the AVCO 6KW loudspeakers and 12 Model 29OC Altec-Lansing loudspeakers are mounted on one wall of the chamber. The four large loudspeakers are powered by a 70,000-watt Westinghouse amplifier, the 12 small loudspeakers by 12 sixty-watt amplifiers. The crossover frequency between the two sets of speakers is 800 cps.

The dimensions of each of the five sides are approximately 7 feet by 7 feet and the maximum distance between any two surfaces is 10.5 feet. The top is slanted at an angle of 12.5° from the horizontal plane; therefore, no two walls in the chamber are parallel. In addition, fillets have been included between adjacent sides

(*Continued on Page* 20)

rigid dummy loads for shock and vibration tests

BRUNO J. FORSHER, Technical Staff, Hughes Aircraft Company

In the environmental lab at Hughes, the author performed some tests and here reports his findings on the validity of using rigid dummy loads in lieu of electronic packages

IN A SERIES of mechanical environmental tests, simulation of sensitive electronic units is desirable to protect working prototypes from abuse, especially when only their mounting devices are the subject of the test. This type of simulation is guided mainly by principles of economy. The simulated load must be simple in design and low in fabrication cost.

As a rule, these are simple weldments of steel or aluminum plates, fashioned only to outline dimensions. Mating latches, pins, bushings, receptacles, and the mass center are maintained. A diagram of a typical simulated part is shown in Figure 1. The dummy loads present a fairly accurate picture of their electrically operative counterparts except that they are much more rigid.

Because of this rigidity, doubt has arisen as to their validity. It has been argued that the increased rigidity may effect mechanical tests—shock tests especially—so that the test engineer can not be sure how effective the mounting provisions will be after the rigidity is removed. This argument is even stronger for equipment that is already vibration-protected.

On the other hand, it could be argued that the lack of rigidity in the average electronic unit is helpful. The thin sheet metal of these units can yield and reduce the chance for permanent distortion. Permanent distortion does occur especially during impact shock testing and is a prominent cause of failure.

The environmental engineer is bound to follow Air Force specifications which call for rigid simulated parts (MIL C 172 B). He knows that he cannot be supplied with unlimited quantities of prototypes which he may wreck endlessly. Neither does he want to overtest the mounting rack while it is being subjected to shock and vibration within limits specified.

To shed light on this problem, I have conducted a few experiments and have collected information that will be of interest to other environmental engineers.

Vibration Testing

Twelve mounting racks of various sizes, ranging in load capacity between 5 and 350 pounds, were tested under forced harmonic vibration in a frequency range between 5 and 500 cps. First, a transmissibility curve was recorded. Transmissibility may be defined as the ratio of the isolated (output) peak acceleration force to the forced (input) peak acceleration force. Data was recorded in steps of five cps of the frequency range between 5 and 60 cps and in steps of 25 cps between 75 and 500 cps. As a rule, the data was first recorded with a test setup using rigid dummy loads and later on with a similar setup (same rack) using working electronic counterparts. Differences between curves of the first and second test setup are less than 5 percent.

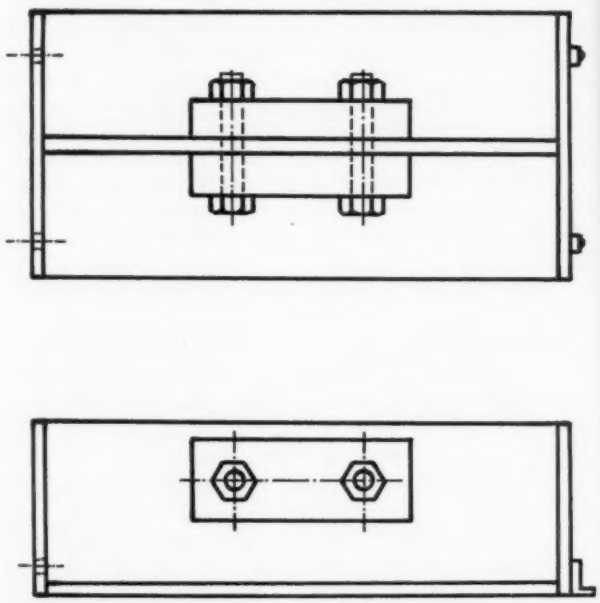


Figure 1. Top and front of a typical simulated electronic unit.

After completion of the data recording, a fatigue test was performed by cycling the setup at a constant input acceleration force of $\pm$ 10 g for about 90 minutes, with 15 minutes sweep time across the frequency spectrum. Whenever a fatigue failure did occur at the rack during the rigid dummy load test, the result was always duplicated at the second test setup, unless the area of failure was reinforced.

(Continued on Page 22)

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get your
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higher altitude
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FASTER
The correct type and size vacuum pump for your specific needs available from the Beach-Russ line of more than 30 single- and two-stage vacuum pump models.
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developments

Saul S. Schiffman of Clifton, N. J., chairman of the board of Tenney Engineering, Inc., manufacturer of environmental test chambers, flew to Europe in September to discuss licensing arrangements with European manufacturers. He inspected an extensive installation of Tenney chambers at the French Air Ministry labs near Paris on a trip that took him to England, Belgium, West Germany, Italy and Spain, as well as to France. Schiffman said that since 1953 the French government has bought a total of 13 large Tenney test units for its missile, rocket and supersonic aircraft development programs. The four most recent of these, costing $140,00, have just been placed in operation.

•

A complete gaseous oxygen and combined environmental test laboratory has been opened in Chatsworth, Calif., by Whittaker Controls Div. of Telecomputing Corporation, Los Angeles. In unveiling the unique new cryogenics facility, Telecomputing President Bob Whittaker announced that the laboratory would serve aviation and missile manufacturers with a source for advanced testing techniques. The lab is equipped and instrumented for environmental-functional testing of gaseous oxygen flow components under acceleration, vibration, ambient temperature and humidity conditions. It is also designed to test electronic, mechanical, pneumatic and hydraulic devices under extreme environmental conditions.

•

New York Testing Laboratories, Inc. (New York City) has announced the expansion of its X-Ray Testing Dept. by the acquisition of new portable equipment and the development of new radiograph techniques. The portable equipment has lead filtering to minimize radiation hazard outside specific target area.

•

Ling Electronics, Inc., Culver City, Calif., has successfully applied a "mobile vibration testing laboratory" to the simulaaed flig'ıt testing of the Douglas DC-8. Marking a departure, according to Ling, from cumbersome test methods that involved piecemeal assembly of heavy lab equipment at the test site, the new trailer includes a complete, self-contained vibration generating and data reception center.

•

Bowser-Morner Testing Labs., Inc., Dayton, Ohio, recently announced the addition of automatic cycling vi-

(Continued on Page 31)

THE ANSWER

to Every OZONE Testing Problem

OZONE TEST CHAMBERS

OREC 0300 series ozone test chambers are entirely automatically controlled with panel instrumentation directly indicating in pphm/volume the ozone concentration at which the test chamber is operating. OREC 0300 series provide ozone concentrations required by all ASTM Specifications, as well as all known Producer, Consumer, and Military Specifications.

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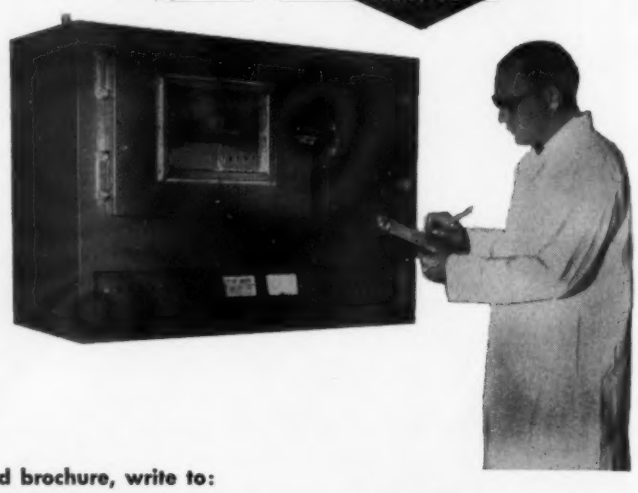
Accelerated ozone test chamber testing and Outdoor ozone testing in the stable desert climate of Phoenix, Arizona are provided at economical rates. Tests are conducted according to ASTM or customer specifications.

OTHER OZONE EQUIPMENT

Static and dynamic stretching apparatus for ozone testing, Laboratory Ozone Generators, Ozone Measurement Instrumentation, and Custom Ozone Apparatus.

AUTOMATICALLY CONTROLLED OZONE TEST CHAMBER

OZONE TESTING OF MATERIALS SERVICE



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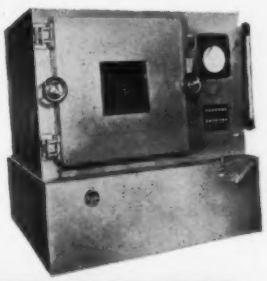

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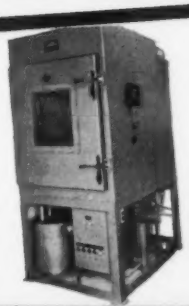

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Environmental Quarterly Will Pay For Articles

The ENVIRONMENTAL QUARTERLY will pay for articles and other editorial material obtained from free-lance writers beginning with 1959 issues, according to Ray H. Mattingley, Editor. From its first issue in October 1955 to the present, Mattingley said, the ENVIRONMENTAL QUARTERLY has depended upon the volunteer contributions of members of Environmental Equipment Institute, Institute of Environmental Engineers, and others vitally interested in the advancement of the state of the art. Exact payments cannot be specified at this time, according to Mattingley, but will depend upon length and quality. The editor invites inquiries from prospective authors.

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Society of Environmental Engineers Has Membership of 168

LEON D. CARVER, Chairman of the Society of Environmental Engineers, in a direct report to *Environmental Quarterly*, has described the S. E. E. as a group of scientists, engineers, and technicians having as its purpose the advancement of the profession of environmental egineering. Carver is an environmental engineer of the High Accuracy Products Corporation.

Formed in early 1956, the Society now has 168 members representing 87 companies—including environmental test laboratories and aircraft, missile, and electronics industries. Most of the membership derives from Southern California but some is from as far away as Phoenix, Ariz., and Salt Lake City, Utah.

In carrying out its purpose, the S. E. E. holds regular technical meetings, tours unique environmental facilities, publishes a bi-monthly newsletter, maintains environmental specification libraries, and supports a large Environmental Standards and Specifications Committee.

The Standards and Specifications Committee works through numerous sub-committees, which are appointed to study and resolve specific problems. Some of these are:

Standard vibration procedures and testing methods.
Location and calibration of vibration instrumentation.
Random-sine vibration equivalents.
Vibration fixtures.
Acoustic simulation.
Study of present specifications.
Future requirements.
Combined environments.
Destructive testing.
Accelerated testing.
Modes of failure.
Quality control.
Reliability.
Transient heating.
Low temperature.

According to Carver, the S. E. E. has been approached by representatives of the Institute of Environmental Engineers with regard to a possible merger of the two societies for mutual benefit. But this, Carver said, is still merely in the proposal stage.

Board of Directors of the S. E. E. for 1958 are: *Chairman*: Carver; *Vice-Chairman*: Mark Christensen, Firestone Guided Missile Div.; *Executive Secretary*: Allen Marshall, Autonetics; *Treasurer*: Jerome Bakalish, Firestone Guided Missile Div.; *Recording Secretary*: Harry Rayfield, General Testing Lab.; *Members-at-Large*: William Vandal (*Past Chairman*), Autonetics; Frank Kramer, Ramo Wooldridge; Noble Bishop, Northrop Aircraft; John Elledge, Hieatt Engineering; and Orville Baer, Gilfillan Bros.

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for sinusoidal and complex motion

MB Manufacturing Company

largest producer of complete vibration test systems

MB Complete Test Systems

AMPLIFIERS

MB Model T999 Power Amplifier

Rated at 100 KVA, this amplifier will drive the largest vibration exciters over their entire operating range under the most adverse inductive and capacitive loading conditions. It has optimum performance characteristics for both sine wave and complex motion testing.

Power Output: 100 KVA continuous over the frequency range 20-5000 cps into any power factor load from 0.2 lead to unity to 0.2 lag. Rated current is available from 5-5000 cps. Full voltage is obtained from 20 to 5000 cps.

Plate Dissipation: 150,000 watts.

Input Power: 320 KW or 270 KW depending on force requirements.

Size: 84″ high x 98½″ wide x 69″ deep.

Weight: Approximately 18,000 lbs.

For complete details, ask for Release No. 109.

EXCITERS

0 to 7000 lbs. force

MB Model C70 Exciter—

Designed for use in or out of environmental test chambers where vibration and other conditions are combined.

Moving element: Approx. 78 lbs.

Stray field: Less than 50 gauss at table with degaussing coil.

Size: 48½″ high x 45″ wide x 46″ deep. Liquid coolant pump and water-cooled heat exchanger supplied. (Air-cooled heat exchanger on special order.)

Maximum inlet water temperature: 80°F.

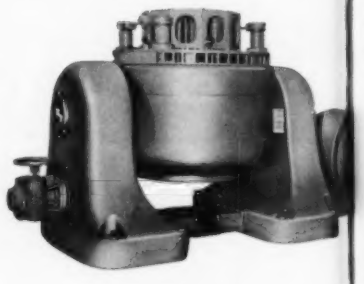
Minimum flow: 25 gpm.

Shaker can be operated continuously under these typical conditions:

Altitude: 0 to 125,000 ft.

Temperature: 0° to +200°F without temperature barrier; −100°to+300°F with one.

Humidity: 0% to 95% relative humidity.



0 to 15,000 lbs. force

CONTROLS

MB Model T68MC Control Console

The model T68MC permits fully automatic sinusoidal vibration tests. It contains:

(1) N570 Automatic Vibration Exciter Control which consists of a servo control, vibration meter and automatic transfer function. This control permits programming and monitoring vibration tests.

(2) N510 control panel which remotely operates the amplifier and monitors vibration exciter currents.

(3) N530 Field and Degaussing Control for vibration exciter.

(4) RP-3 Recessed Panel for quick disconnect hook-up to amplifier and exciter.

MB Model T88 Complex Motion Console

This console puts within arms' reach all the controls required to round out and equip the sinusoidal system of vibration exciter, power amplifier and control console to perform complex or random motion testing. It is complete, easy to use.

FEATURES

- Equalizes for 10 peaks and 10 notches, and for exciter/specimen relationships.
- Equalizes response by active analog computer circuits.
- Compensates for "mass offset" for any table loading condition.
- Corrects for high "Q"—over 40 db peak, 40 db notch at low and high frequencies.
- Records frequency response by X-Y plotter technique.

MB Model T67 Compensation Console

Contains one less cabinet section than the T88 but is similar in function.

esigned, built, and serviced by MB

MB Model T996 Power Amplifier

An amplifier matched to the needs of the shaker, this power supply has been designed for both sine wave and complex motion testing. It is rated at 50 KVA, and will handle all inductive and capacitive loads placed on it by the vibration exciter and specimen over its entire frequency and load range.

Power Output: 50 KVA continuous over the frequency range 20-5000 cps into any power factor load from 0.2 lead to unity to 0.2 lag. Rated current is available from 5-5000 cps., full voltage from 20-5000 cps.

Plate Dissipation: 100,000 watts.

Input Power: 220 KW or 170 KW depending on force requirements.

Size: 84" high x 98½" wide x 69" deep.
Weight: Approximately 14,000 lbs.

For complete details, ask for Release No. 108.

COMMON SPECIFICATIONS

Distortion: Typical harmonic distortion measurements are ½% from 50 to 1000 cps. Guaranteed less than 3% 20-2000 cps at full rated voltage into the resistive load used for 100 KW output.

Frequency Response: Typical ±0.5 db 5-5000.

Noise and Hum: At least 60 db below full output.

Phase Response: Less than 15 degrees from 10 to 5000 cps.

Filaments: Regulated supply, no adjustments necessary. Output tubes voltage regulation is ±1% for ±10% changes in line voltage.

Input Power: Rated KW at nominal line voltages of 400/420/440/460/480, three phase, 60 cps. Line voltage may fluctuate ±10% from these nominal voltages. 3.5 KW at 117 volts ±10%, 1 phase, 60 cycle power is also required.

MB Model C100 Vibration Exciter—

Forced air cooled electrodynamic exciter capable of continuous duty at rated force.

Moving Table Assembly

Mounting table: 27" diameter outer bolt circle. 31 stainless steel mounting points.

Supports: Unique rocker suspension system assures long flexure life.

Weight: Approx. 285 lbs.

Size: 61½" high x 133½" wide (including blower) x 53" deep.

Base: Trunnion mounted for operation in any position from vertical to horizontal. Positioned by hand-operated reduction gear. Built-in vibration isolators.

Stray Field: Less than 75 gauss with degaussing coil.

0 to 25,000 lbs. force

MB Model C200 Vibration Exciter—

The ultimate in high power, high frequency electrodynamic exciters. Liquid cooling provides increased efficiency and quiet operation.

Moving Table Assembly

Mounting table: 27" diameter outer bolt circle. 31 stainless steel mounting points.

Supports: Unimode suspension (pat. pend.) Linear motion throughout a 1-inch stroke.

Weight: Approx. 350 lbs.

Size: 65½" high x 105¾" wide x 62¼" deep.

Base: Trunnion mounted for operation in any position from vertical to horizontal. Positioned by hand-operated reduction gear. Built-in vibration isolators.

Stray Field: Less than 20 gauss without degaussing coil.

SYSTEM PERFORMANCE

	Exciter	C70	C100	C100	C200	C200
	Amplifier	T996	T996	T999	T996	T999
SINE WAVE	Range cps	5-2000	5-2000	5-2000	5-2000	5-2000
	Force-lbs Vector	7000	12,500	15,000	21,500	25,000
	Velocity limit	none	none	none	45"/sec.	60"/sec.
	Displacement limit	0.5"DA	0.5"DA	0.5"DA	1.0"DA	1.0"DA
	Max. Table Load					
	10 g Vector	625 lbs.	965 lbs.	1215 lbs.	1805 lbs.	2155 lbs.
	20 g Vector	275 lbs.	340 lbs.	465 lbs.	730 lbs.	905 lbs.
	30 g Vector	156 lbs.	131 lbs.	215 lbs.	370 lbs.	790 lbs.
COMPLEX MOTION	Frequency Band cps	20-2000	20-1300 (a)	20-1300 (a)	20-2000	20-2000
	Rms force—lbs.	5000	8850	10,600	10,700	17,700
	Peak force—lbs.	15000	26550	31800	32100	53100
	Max. Table Load					
	30 g Peak—10 g rms	425 lbs.	600 lbs.	775 lbs.	725 lbs.	1425 lbs.
	60 g Peak—20 g rms	175 lbs.	157 lbs.	245 lbs.	190 lbs.	540 lbs.
	90 g Peak—30 g rms	90 lbs.	0	70 lbs.	0	245 lbs.

(a) any rigid mass.

largest manufacturer of complete vibration test systems

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A DIVISION OF TEXTRON INC.
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MB provides *complete* systems. It builds the electrodynamic exciter, the power amplifier, and the specialized controls for their operation. Each system is integrated and matched as only the manufacturer of all elements comprising that system knows how. Results show it—in performance, in serviceability.

LEADING EXPERIENCE

MB has been recognized as vibration engineering headquarters for over 12 years. It pioneered in electrodynamic exciters. It has built close to 1000 amplifiers in that time. Over 2000 MB integrated systems have been satisfying the most critical specifications in the field.

BROADEST SCOPE

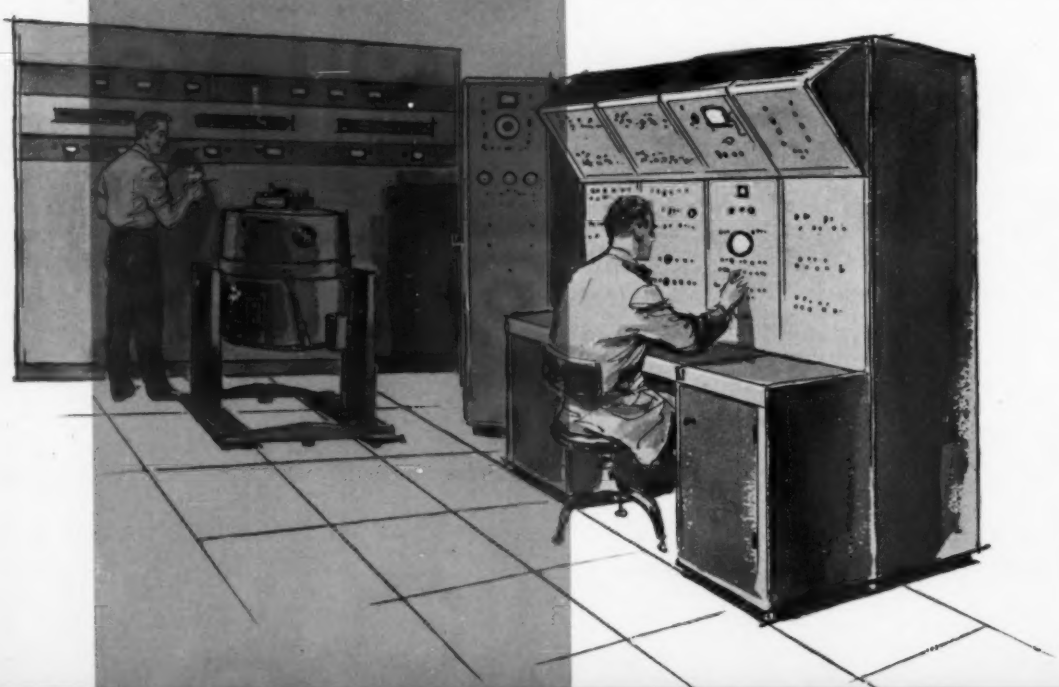
The unsurpassed total of MB vibration engineering experience is reflected by the range of test systems available today. Shakers range from as low as 1.2 pounds force to the largest in existence today—25,000 pounds force. Amplifiers go up to 100 KVA continuous output. Control Systems satisfy the most advanced complex motion techniques as well as sinusoidal vibration and fatigue testing.

UNDIVIDED RESPONSIBILITY

MB is the prime manufacturer of all units comprising these vibration test systems. It offers undivided responsibility for system performance; one source of supply to back up reliability; one warranty for highest quality materials and workmanship.

FULL FIELD SERVICE

The largest field service organization of vibration specialists is on call nationwide to users of MB test systems. They are technically trained and qualified to provide service on the *complete* systems.



IEE Tells Membership Of New Management

Early in October, the Executive Committee of the Institute of Environmental Engineers made, in effect, the following announcement to its membership over the signature of its President, Roger J. Amorosi:

The IEE Executive Committee met on September 10 to discuss ways and means of establishing the IEE as an independent professional institute, on a financially sound basis. To reach this objective, several plans were offered. The Executive Committee empowered a liaison committee to act in its behalf and meet with Dr. George D. Wilkinson, General Manager, and the Environmental Equipment Institute to discuss and satisfy this objective. The committee consisted of R. Amorosi, H. Jones, J. Cammarata, A. Billet, and H. Sander.

The liaison meeting took place on September 11, and the following understandings were reached:

Pending the approval of the IEE membership, IEE by-laws will be changed to eliminate the Joint Council with the EEI. All other previous agreements or ties with the EEI will be abolished.

The HANDBOOK OF THE ENVIRONMENT *will be the sole property of the IEE, and all IEE rights to the* ENVIRONMENTAL QUARTERLY *were relinguished to the EEI. In return, the EEI has absorbed debts of the IEE prior to September 11, 1958. The IEE notified the EEI that the IEE will initiate, as soon as is feasibly possible, a new environmental journal commensurate with its professional status.*

At its annual technical meeting, the IEE will sponsor an equipment exhibit area. Any reputable company will be permitted to exhibit its equipment or services.

To reduce expenditures, the services of Dr. George D. Wilkinson as General Manager of the IEE were terminated. John Regazzi was appointed General Manager, on a volunteer basis, until the November meeting of the IEE Executive Committee. Regazzi is head of Environmental Section, American Bosch Arma Corporation.

The Executive Committee wishes to publicly express its appreciation both to the EEI and to Dr. George D. Wilkinson for all they have done in initiating our engineering organization.

The Executive Committee is confident that the above actions are advisable and will result in a strong, financially-sound, progressive society.

The new address for the IEE is P. O. Box 341, Mineola, L. I., New York.

For the IEE Executive Committee:

ROGER J. AMOROSI
President, IEE

I E E Complete Plans - For 1959 Meeting

According to Roger J. Amorosi, President, the Third Annual Meeting of the Institute of Environmental Engineers will be held at the La Salle Hotel in Chicago on April 22, 23, and 24, 1959. Amorosi is President of Parameters, Inc. Technical papers covering the following fields will be presented:

The hyper-environment and its effect on equipment and personnel in the vehicle and in the laboratory; Satellite programs—the environmental problems; The expanding role of the environmental laboratory and its personnel; Ground support equipment—designing for the environment; Re-entry and its problems; Military cryogenics; Radiation effects; And problems in dynamics and acoustics.

The IEE is sponsoring an equipment exhibit area during the three day meeting during which environmental test equipment manufacturers and instrument suppliers will display and discuss their equipment.

The following committee has appointed, Amorosi said: *Meeting chairman*: Arthur Billet, Vickers, Inc., Detroit, Mich.; *Program Committee Chairman*: Raymond Yaeger, Chrysler Corporation, 5514 Hartlein Drive, Warren, Mich.; *Facilities, Publicity, and Registration Committee Chairman*: Ernest Corduan, c/o Vap-Air, 6444 West Howard Street, Chicago 31, Ill.

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- *ACCELERATION* (centrifugal)—AMERICAN MACHINE & FOUNDRY CO. Alexandria Div.
- *SOLAR HEAT*—GIANNINI PLASMADYNE CORP.
- *DYNAMIC MEASUREMENT* MB VIBRATION PICKUPS & METERS, COLUMBIA RESEARCH LABS. ACCELEROMETERS, CHADWICK-HELMUTH STROBE SCOPE AND CAMERA SYNCRONIZERS, LYCOMING TEMPERATURE ACCELERATION INDICATORS

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ROCKET NOISE

(*Continued from Page 9*)

that are 90° or less apart to eliminate acute angles in the chamber. There is a removable section in the top of the facility so that large specimens may be placed in the chamber with an overhead crane.

Suspending Specimens

Test speciments are suspended by soft springs or bungee cord from 15 eyebolts embedded in the concrete walls. A plate is embedded in the floor for rigid mounting of test specimens. On one wall is an instrumentation patch panel. This panel includes shielded, high current-carrying and radio-frequency connectors as well as pressure ports for hydraulic and pneumatic connections. With the instrumentation patch panel it is possible to operate complete systems during acoustic noise tests.

Either a random generator with two band pass filters, or a two channel tape recorder is used to excite the amplifiers that drive the speakers. The noise generator provides a white frequency spectrum, and the bandpass filters control the bandwidths of the noise to each set of speakers. A two channel tape recorder is sometimes used to provide the signals to the two sets of amplifiers. By pre-recording a compensated noise signal, the frequency spectra in the reverberant chamber can be changed, and discrete or narrow-band noise environments can be produced.

For most acoustic noise tests, the outputs from several

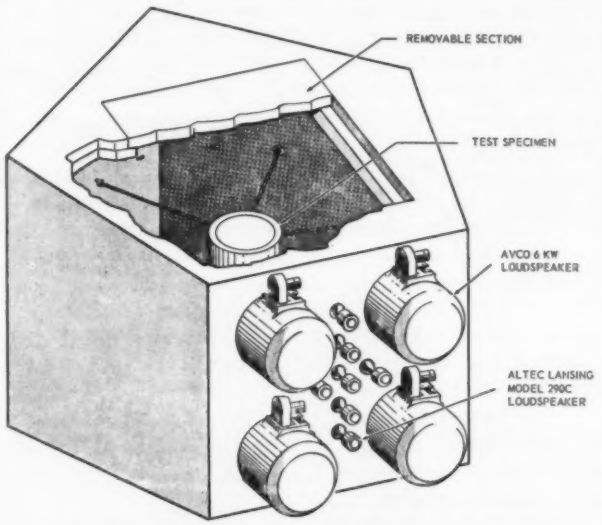


Figure 5. AVCO 900-cubic-foot reverberant chamber.

microphones are recorded on a seven-channel CEC tape recorder. Following the test the information is played back through Bruel and Kjoer one-third octave band filters and is analyzed. Figure 6 is a block diagram of the equipment used to produce, record, and analyze the noise.

The pentagonal reverberant chamber is capable of producing random noise at a sound pressure level of

(*Continued on Page 24*)

New accessory permits Genisco C181 Rate of Turn Table to be operated at any angle from horizontal to vertical

Fred Davenport, Lockheed radio-radar technician, tests pitch-yaw gyros used in the *Electra*, Lockheed's fast, new prop-jet, on the first *tiltable* Genisco C181 Rate of Turn Table.

A new, vertical-drive accessory permits the C181 to operate in *any* position. Now, gyros or complete gyro packages can be tested at any angle up to 90° from horizontal, either side of center, without changing the test set-up.

With the accessory installed, overall performance of the turntable is unaffected by its position. Rotation is infinitely variable from 0.01° to 1200° per second. Constancy of angular velocity is within 0.1%, including wow and drift errors.

The new vertical drive accessory can be installed at the factory, and is also available in kit form for modification by users of machines already in the field. The new tilt stand (shown above) provides a convenient method of tilting and accurately positioning the machine at any angle.

Detailed information on both the vertical drive accessory and tilt stand is available and will be sent upon request.

More than 400 Genisco Rate of Turn Tables are now in use.

ACCESSORIES ADD TO ACCURACY AND CONVENIENCE OF THE C181

Braking System—Generates a step impulse of angular deceleration. Particularly useful in evaluating damping characteristics of rate gyros and angular accelerometers.

Precision Strobe—For use in monitoring rates where line frequency is questionable or where gyro accuracy is better than line frequency.

Slip Clutch—Allows table to be stopped by hand for minor adjustments to test package while drive system continues to operate.

Low Rate Readout—For accurate rate indication below 10°/sec.

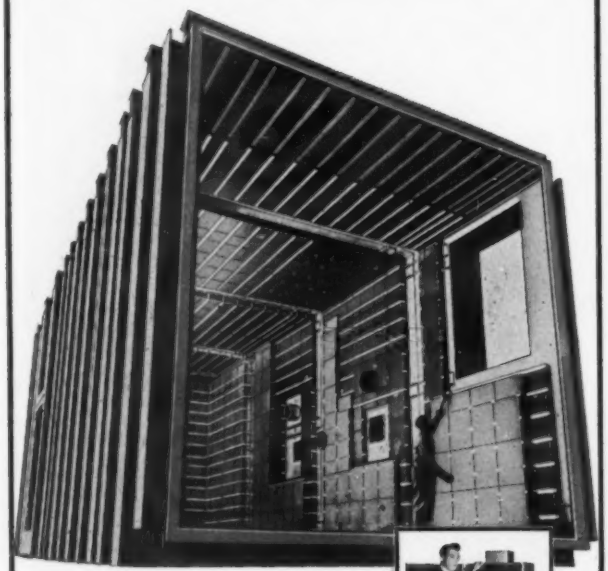
Mounting Stands—Available in portable, fixed and the new tilt models.

Genisco INCORPORATED

2233 FEDERAL AVENUE • LOS ANGELES 64, CALIFORNIA

Tenney

offers widest range of environmental test equipment!



Temperatures from —150°F to 1250°F; altitudes to 350,000 feet; as big as a house, as small as a typewriter . . . and everything in between.

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WORLD LEADER IN ENVIRONMENTAL TEST EQUIPMENT

RIGID DUMMY

(*Continued from Page* 10)

Shock Testing

A special impact shock test was conducted that appears to be of particular significance. Two identical small mounting racks were used, designed for an electronic black box weighing about 15 pounds. Units were

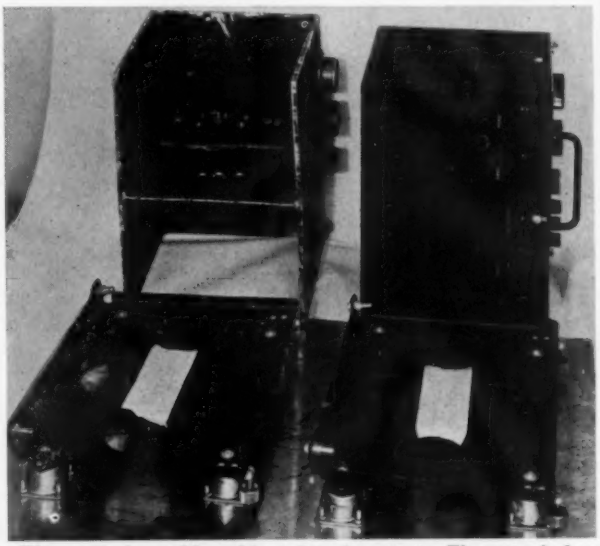

Figure 2. Assembly subjected to drop tests. The actual electronic unit is shown at right; the dummy load at left.

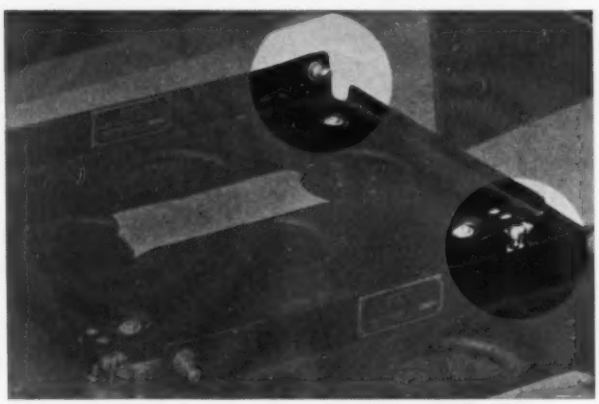

Figure 3. Distortion of rack used with dummy load.

mounted by means of two guide pins anchored in the upright lip of the rack and by a pair of conventional screw latches located below the front rim. On the left-hand rack (fig. 2), a dummy load of the typical design was attached. At the right hand rack, the actual electronic unit was mounted. Both racks were attached to a platform with their proper set of shockmounts and the whole setup was then subjected to a series of drops in an orientation parallel to the front edge of rack or unit.

First, three drops of 30 g magnitude were performed with the Barry MVD 150 impact machine. A slight dis-

(*Continued on Page* 27)

NEW PRODUCTS

For more information, please circle the key number on Reader Service Card.

1—MB Type 128-1 Vibration Pickup. Used in flight testing of a recently-accepted air-to-surface missile, with data being telemetered to ground recorders. Magnetically damped. High natural frequency. Measures vibratory motions with up to ± 5g unidirectional steady acceleration superimposed, with little change in sensitivity over wide temp. range (—65° to +250° F). MB MANUFACTURING CO.

2—High-low temperature test machine for use in tensile testing of small component assemblies. Test chamber mounted remote from its power pack. Designed for insertion in tensile test machine. Adjustable from 46 to 60" from floor. Temp. range: +80° to —120° F. Chamber is 9" long by 12" wide by 14" high, with frostproof multipane observation window. Special heavy sponge rubber door fitting allows insertion of test specimens without loss of temperature, and permits limited vibratory motion of specimen. CINCINNATI SUB-ZERO PRODUCTS.

3—Three new centrifuges feature a high-torque version of a ball-disc integrator drive system said to be smoother and more efficient than others now in use. Maker claims constancy of rotation to be better than 0.05% at any speed setting. Transmission speed is infinitely variable from 0 to 800 rpm. Building block design: Machines assembled from six basic, off-the-shelf components: drive system, motor, test compartment, boom, console, accessories. Customer selects components for specific needs. Size of the three models: 30" table, and 60" and 96" arms. GENISCO, INCORPORATED.

4—Portable and stationary hydraulic test bench for pressures up to 5,000 psi. Variable vol. of 1.7 gpm to 10.5 gpm. Power rating to 30 hp. Designed for MIL 0-5606 oil but accommodates wide variety of fluids. Flowmeter error of under 2% guaranteed for full range of flow. Air heat exchanger for hydraulic components and systems. Meets most Air Force oil temperature control. Precision testing of all types of hydraulic components and systems. Meets most Air Force and Navy specs. for missile testing. THE RUCKER COMPANY.

5—Advanced design temperature test chambers. Thirty cu. ft. work space. Std. Series 30 units feature low temp. ranges of —40°, —100°, and —120° F; high temp. ranges of +240° or +350° F optional. Also optional, these units can provide for relative humidities of 20 to 98% (limited by +35° F dewpoint) and 5% at +160° F. Heliarc welded, stainless steel interior with a positive seal dual door gasket, the Series 30 require no installation service other than plug-in electrical connection. TENNEY ENGINEERING, INC.

6—Efficiency Recorder affords visible start-stop time record. Single line on cylindrical chart is continuously readable in percentage of time over entire period being recorded. Maker claims numerous applications in the environmental lab. Can be connected to respond to the motion of virtually any device via snap switch, vibration pick-up, or photo cell. GORRELL & GORRELL.

7—BVA-25 mechanical vibration machine. Frequencies 2 to 20 cps. Double amplitudes up to 1" max. obtained by a single adjustment. Employs an eccentric shaft driven by a small variable-speed drive to vibrate a 10" square table in the vertical plane at frequencies from 2 to 20 cps. Table motion is linear in the vertical plane, and specimens weighing 25 lbs can be vibrated at accelerations up to 20g. L.A.B. CORPORATION.

(Continued on Page 27)

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Los Angeles Chapter of I. E. E.

Installs First President

Election of William H. Grumet as the first President of the Los Angeles Chapter of the Institute of Environmental Engineers was recently announced by the Chapter's executive committee. This Chapter has just been formed to affect complete interchange of ideas and information pertaining to environmental testing and related fields.

Grumet, at 31, is Manager of American Laboratories, an independent Environmental Test Lab of American Electronics, Inc. He has set up two of the leading environmental test labs on the West Coast. He holds a BS degree in Electrical Engineering and a BA degree in Business Administration from Columbia University.

Grumet is a member of IEE, SEE, AES, ISA and TAU BETA PI Societies. He has stated that one of his goals during his tenure of office will be to affect a harmonious working relationship between the IEE and the Society of Environmental Engineers so as to improve the field of Environmental Testing.

Executive Committee of the Los Angeles Chapter is: *President*: Grumet; *Vice-President*: Bruno J. Forscher, Hughes Aircraft Co.; *National Director*: Jack Mason, Marquardt Aircraft; *Secretary*: Robert Law-Rie, Hughes Aircraft Co.; *Treasurer*: Ronald Sneddon, Wyle Laboratories; *Director*: Loren Patrick, Stokes Co.; *Director*: Allen J. Silver, Radioplane; *Director*: William Talbot, California Testing Laboratories; and *Director*: John S. Windele, Wyle Laboratories.

ROCKET NOISE *(from p. 20)*

152 db. The one-third octave band frequency spectrum of the acoustic noise in the chamber is presented in Figure 7. Superposed on this curve is a one-third octave band spectrum that is a typical acoustic noise testing specification* for components of a rocket-powered guided missile. From the curves of Figure 7, it is apparent that the noise spectrum produced in the pentagonal reverberant chamber is within ± 3 db of the rocket engine

(Continued on Next Page)

* The procedure outlined in "On the Prediction of Acoustic Environments from Rockets," by V. Chobotov and A. Powell, Guided Missiles Div., Ramo-Wooldridge Corporation, June 3, 1957, was used to calculate the sound pressure level and frequency spectrum for this test specification. The procedure is for estimating external noise environments and assumes far field conditions exist (distance from source many times the wave length of the sound frequency and the diameter of the exit nozzle). For our testing specification we calculated the attenuation due to the distance from the rocket source but did not include any attenuation due to directivity of the sound. In addition, we did not assume any attenuation through the structure of the missile; therefore, the over-all sound pressure level of this specification is a conservative estimate of the actual internal noise environment.

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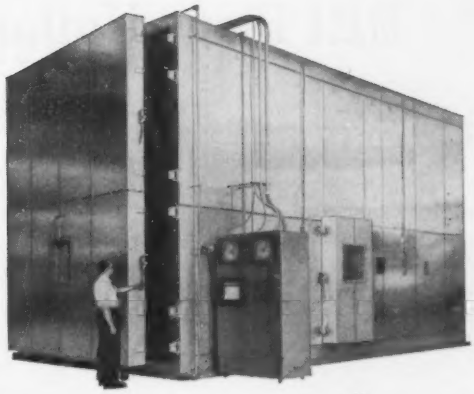
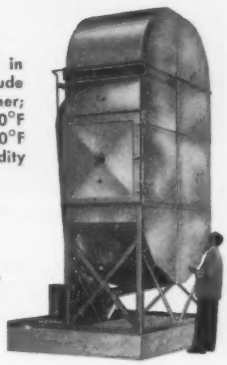
Any size test chambers are available from American Research. Room shown above permits a large truck to deliver the test item to the interior without double handling. Components or completed items can be tested through a complete range of simulated environments.



◀ Altitude chambers in any size — Altitude 200,000′ or higher; temperature +500°F and higher to −100°F and lower; Humidity 20% to 95%.



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spectrum from 125 cps to 3000 cps.

The spectrum in the chamber drops sharply at 125 cps. This happens for two reasons: the smallness of the horns used to couple the loudspeakers with the chambers, and the fact that the distance between the walls of the chamber is less than the wave lengths at the lower frequencies. To have efficient coupling at 50 cps, horns with a minimum diameter of 3.6 feet would have to be used between the loudspeakers and the chamber. The sound pressure level of random noise produced at the mouth of a horn this size would be 143 db. In addition, with four horns this size, one wall of the reverberant chamber would be lost. A compromise was made based on the low frequency cutoff, the effective reverberant area of

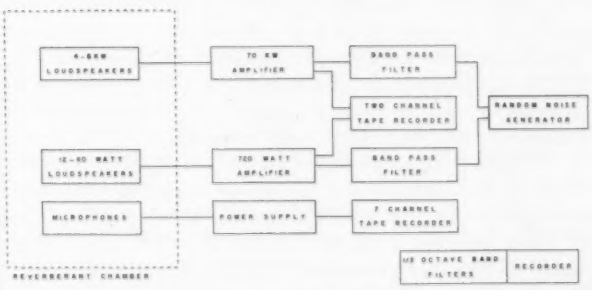

Figure 6. Block diagram of acoustic noise test equipment.

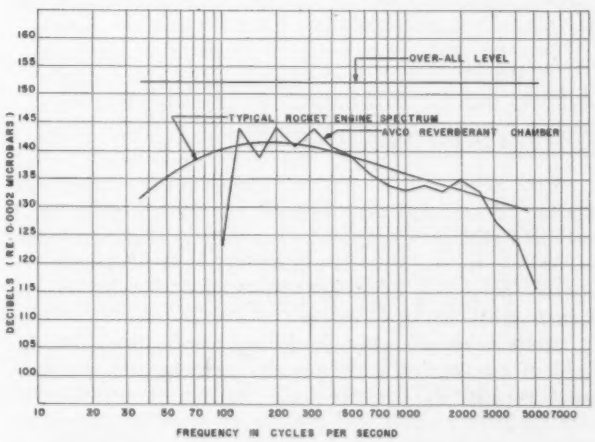

Figure 7. One-third octave band frequency spectrum—reverberant chamber.

the wall with the speakers mounted, and the sound pressure level at the mouth of the horns.

The high frequencies of the noise spectra produced in the chamber drops off at 3000 to 4000 cps, which is approximately the upper frequency limit of the mid-

(*Continued on Page* 28)

EEI Plans Uniform Cost Accounting System At Semi-Annual Meeting

Dr. George D. Wilkinson, General Manager of the Environmental Equipment Institute, at the semi-annual meeting October 3 in Cincinnati, presented a massive report to the membership on a system devised by Wilkinson for uniform manufacturing cost accounting within the membership.

Dr. Wilkinson, whose duties as General Manager of the EEI require a relatively small amount of his time, is President of Wilkinson Associates, a firm of consultants in management with headquarters in Prnceton, N. J. In his capacity both as EEI General Manager and as expert advisor to top management, Dr. Wilkinson has developed the EEI Cost Accounting System. The System was devised after a careful study of the existing cost accounting practices of the various members of the EEI.

Members of the EEI were presented by Dr. Wilkinson with a "Standard Chart of Income and Expense Accounts for Manufacturers of Environmental Test and Related Equipment." EEI members plan to report 1957 figures immediately so that a consolidated industry report can be made at once.

Cost figures for 1958 will be published in time for the EEI's Annual Meeting in April 1959. In the processing of industry figures for the consolidated reports, the names of individual companies will be kept confidential and the Annual Reports will show companies by means of coded numbers only.

Another highlight of the EEI's meeting was discussion of the fact that Institute of Environmental Engineers now has achieved complete autonomy and is no longer connected with the EEI. According to Dr. Wilkinson, the Institute of Environmental Engineers originated as the child of the EEI and began its existence as the Science Section of the EEI in 1955. By the summer of 1956, the Science Section had become so large and vigorous that the EEI granted it partial autonomy, assisted it to incorporated, and augmented it resources with financial support.

According to Dr. Wilkinson's report to the EEI meeting, the IEE has changed its headquarters location and appointed a new manager on a volunteer basis in order to operate more economically for the time being.

The EEI members present were unanimous in wishing the fledgling engineering society the best of luck and success in its determination to become totally independent.

Attending the meeting were: *President,* R. J. Jacobson, President, Cincinnati Sub-Zero Products; *Executive Vice Prsident,* Charles C .E. Harris, President, Harris Refrigeration Company; *Executive Committee Member,* Monroe Seligman, President, Tenney Engineering, Inc.; *Executive Committee Member,* Jack Shamroth, President, American Research Corp.; Charles Earl, President, Alpha Electric Refrigeration Co.; Don Magnuson, Hudson Bay Co., Div. of Labline, Inc.; and Dr. Wilkinson.

LING ELECTRONICS ACQUIRES THE CALIDYNE COMPANY

Ling Electronics, Inc., of Culver City, Calif., and Dallas, Texas, has acquired all of the common stock of the Calidyne Company, Inc., of Winchester, Mass., according to a joint announcement by Cameron G. Pierce, president of Ling Electronics, and Robert C. Lewis, president of Calidyne.

Both companies are leading manufacturers in the field of electronically driven vibration testing systems—used principally for pre-flight testing of components and parts for aircraft and missiles involved in supersonic flight.

One of the first examples of combined company operations, Pierce said, is development of a giant new Ling-Calidyne vibration testing system. The new system employs a power amplifier rated at 175,000 watts output, coupled to an electrodynamic shaker delivering 25,000 pounds force. It will be employed by a prime military contractor engaged in developing an advanced type ballistic missile.

Both Lewis and Phillip C. Efromson, the chief executives of Calidyne, will continue in their present capacities with the company. Engineering, sales and production personnel will remain intact.

NEW YORK CHAPTER OF IEE SPONSORS TECHNICAL SYMPOSIUM AND PRODUCTION EXHIBITION

The New York Metropolitan Chapter of the Institute of Environmental Engineers will hold a Technical Symposium and Product Exhibition on Thursday and Friday, November 20 and 21, 1958 at the Hotel Henry Hudson in New York City. The product exhibition will afford manufacturers and suppliers of environmental equipment and services an opportunity to display to an estimated 400 engineers and scientists.

Plans for the show include publication of a Program Book to be distributed by mail on a nation-wide basis late in October. All arangements are under the direction of John Regazzi, Program Committee Chairman. Regazzi is Head, Environmental Section, Arma Div., American Bosch Arma Corp.

NEW PRODUCTS (*Continued from Page 23*)

8—Miniature, single-coil, variable-reluctance, diaphragm-type transducer for use as variable inductor in commercially available inductance and reactance controlled FM/FM subcarrier oscillator system. High reliability under environmental extremes. Differential, gage, and absolute models are offered with a wide selection of pressure ranges between 0 - 10 psi and 0 - 5000 psi. ULTRADYNE, INC.

9—"Armorox" thermocouple for measuring temperatures to 2,000°F at pressures to 50,000 psi. Metal-sheathed, ceramic-insulated. Easily bent around twice its own diameter to get into out-of-the-way places. THE BRISTOL COMPANY.

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RIGID DUMMY (*Continued from Page 22*)

tortion of the base panel and at the right-hand mounting pin and rear lip (Fig. 3) was noted. To make the distortion more pronounced, another two drops of 50 g magnitude were added. The photographs shown as Figure 2 with an enlargement as Figure 3 were taken at this point. The distortion of both racks is nearly identical.

To the extent that conclusions may be drawn from limited tests, it appears to me that only mass simulation and simulation of mounting are of significance in the performance of a test specimen (such as a mounting provision) regardless of the rigidity of the attached dummy load or unit.

END

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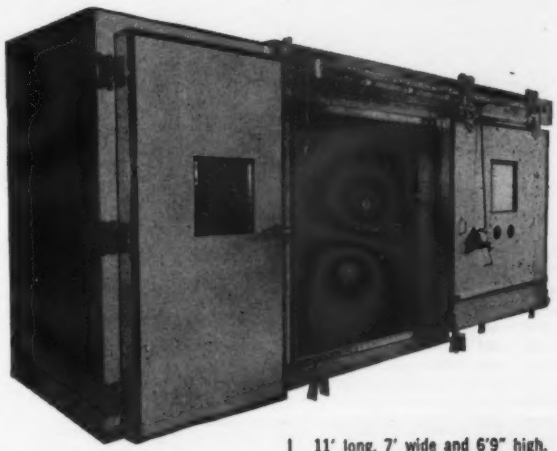

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This 2 cu. ft. unit is ideal for close temperature control testing of parts, equipment, finishes, etc. Has a range of minus 120° to plus 300° F., with a frost-proof observation window in hinged lid and interior illumination. Indicating control, fin coil and blower circulator and a 500 watt heater.

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ROCKET NOISE (*from p.* 25)

range speakers used for the chamber. The upper frequency limit could be extended by adding high frequency loudspeakers to the chamber.

The frequency spectra vary at different positions in the chamber but the over-all sound pressure levels are within ±2 db throughout the chamber. The frequency spectra, the over-all sound pressure level, and the reverberation time are affected by the presence of a large test specimen in the chamber. Low frequencies are attenuated more than high frequencies when a large specimen is tested. This happens because the distance between surfaces is much shorter and becomes comparable to the wave lengths of the low frequencies.

The absorptivity of the surface of a test specimen will affect the over-all sound pressure level and the re-

(*Continued on Page* 32)

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...up to: 150 G
8,000 lbs.
400,000 G-lbs.

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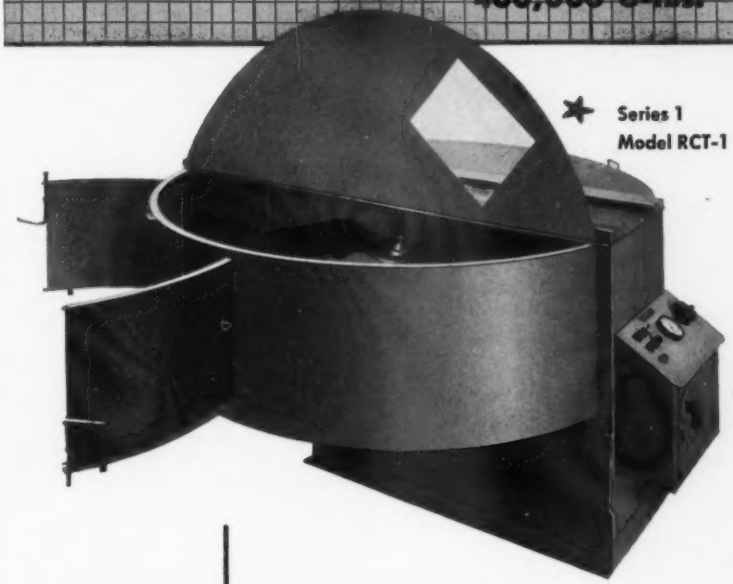

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G-rating: 1 to 150
Test radius: 18" to 46"
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Test radius: 96" to 240"
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G-rating: 1 to 100
Test radius: 264" to 420"
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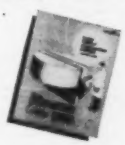

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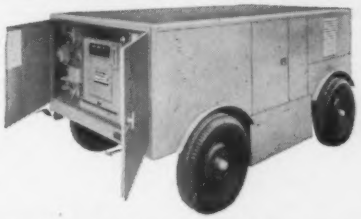

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★ **Series 20 Model RCT-21**

View of 22' radius arm and powerhead installed in test pit. This large Series 20 unit is designed for testing 4,000 lb. specimen at 100 G-rating.

A Defense of
VIBRATION MEASURING INSTRUMENTS

GEORGE M. WATT, Bendix Products Div.—Missiles

This discussion is in defense of vibration instrumentation with respect to apparent discrepancies under practical test conditions. Test engineers and technicians soon become aware that various brands of instrumentation do not report identical acceleration values under identical vibration test conditions. This has also been a special unrecognized problem that has existed between the subcontractors and the prime contractor at their respective plants because of the differences in the available instrumentation. This subject is part of the orientation lecture for vibration testing in the Environmental Laboratory at Bendix.

It is quite standard procedure that additional vibration instrumentation will be installed in a package that is failing under the specified vibration tests. If the additional vibration instrumentation does not sense and interpret the vibration in an identical manner as the original instrumentation, the designers, being human, may condemn everything and believe nothing. The test engineer is indeed in a difficult position if he has not prepared to defend his instrumentation. The origin of the problem is so often overlooked: *the response of packages to sinusoidal forces is not necessarily sinusoidal vibration.* To make matters worse, the excitation forces are not very good sinusoids, particularly from rotary (alternator) powered shakers.

Suppose we have four commercial millivolt instruments. The first is normally used to measure true rms regardless of waveform (known as the "thermocouple meter"). The second instrument is a vacuum tube voltmeter that senses the average of the voltage being measured (known as the "average meter"). The third meter is a vacuum tube voltmeter that senses the peak of the voltage being measured (known as the "peak meter"). The fourth instrument is an oscilloscope that will serve to display the exact voltage at all points making up the voltage cycle.

Each of the various meters will probably have one rms scale along with its special purpose. To eliminate confusion by rms sensing and rms reading, we shall have the meters matched to accelerometers and calibrated in the instrument room to new scale faces of 0 to 20 g. The Instrument Room, of course, is calibrated with carefully controlled sinusoidal motion of accurate displacement and frequency.

To complete the plot, I will take issue with the term *sinusoidal* in the phrase "sinusoidal vibration testing." The term indicates that one is not speaking of random vibration, but it does not limit the vibration to sinusoidal motion as comomnly used. The point being developed is that it would be an erroneous assumption that all signals from the accelerometers are close to being sinusoidal voltages under so-called sinusoidal vibration testing. This is strictly experience from the practical testing laboratory. If an electronic package is so rigid and resonant-free that the accelerometer sees no distortions and violent responses, there was probably no vibration problem in meeting the type test specificaton regardless of whether the test conductor used any of our four instruments or just listened and tested with devilish intent.

Let us now subject our four sensing systems of accelerometers and associated meters to accelerations not necessarily sinusoidal. The meters may not read alike, yet each is honest in its own way. The oscilloscope will show exactly what is taking place. The meters are much more convenient and easier to read—even when they are wrong.

Example 1—10g (peak) Sinusoidal Vibration Acceleration. The thermocouple meter will sense rms which is 7.07; it is calibrated at 1.414 times rms; therefore, it will read 10. The average meter will sense 6.4; it is calibrated at 1.57 times average; therefore, it will read 10. The peak meter will sense 10; it is calibrated at unity; therefore, it will read 10.

Example 2—10g Square Waveform Acceleration. The thermocouple meter will sense 10, but will read 14 (1.414 x 10). The average meter will sense 10, but will read 15.7 (1.57 x 10). The peak meter will sense and read 10.

Example 3—10g Triangular Acceleration. The thermocouple meter will sense 5.8 but will read 8.2 (1.414 x 5.8). The average meter will sense 5 but will read 7.85 (1.57 x 5). The peak meter will sense and read 10.

Example 4—An Unbalanced Square Waveform of +10g and −5g. The plus and minus areas must be equal if the position of the shaker in the laboratory is to be stationary. This waveform is a simplified illustration of a mechanical interference of a package during vibration where a slapping causes high acceleration pulses in one direction only. The thermocouple meter will sense 10 for 1/3 of the period and 5 for 2/3 of the period; therefore, it will read 9.4 $\left(\frac{10 + 2 \times 5}{3}\right.$ times 1.414).

The average meter will sense 10 for 1/3 of the period and 5 for 2/3 of the period and read 10.5 $\left(\frac{10 + 2 \times 5}{3}\right.$ times 1.57). The peak meter, if a half-wave rectifier

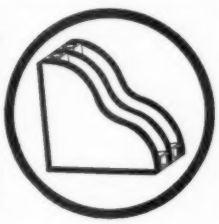
(quite likely), will sense and read either 10 or 5, depending upon the polarity being sensed. If the peak meter uses full-wave rectification, it will sense the highest peak and read 10.

There are additional peak-to-peak sensing instruments that have been neglected in this discussion. But I have given enough examples to emphasize that vibration instrumentation is easily misinterpreted unless you know the meaning of the information presented. Certain types or brands of instruments will continue to be criticized as inaccurate when in reality the instrument is honest, because the user does not understand the data presented to him.

The examples cited were not intended to favor peak sensing instrumentation. The type of instrumentation favored depends upon the belief of the given engineer as to what is the measure of damage potential. There are, of course, many other factors to be considered when choosing optimum instruments—cost, needed accuracy, response time, convenience, et cetera.

END

THERMOSEAL



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DEVELOPMENTS *(from p. 12)*

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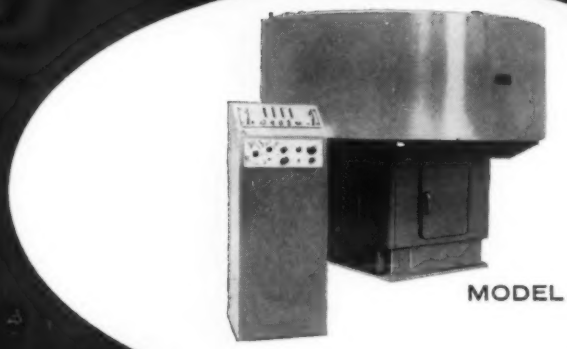

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B-8-A	8 FEET
B-10-A	10 FEET
B-12-A	12 FEET
T-13-A	13 FEET
T-16-A	16 FEET
A-35	35 FEET

ROCKET NOISE *(from p. 28)*

verberation time in the chamber. The over-all sound pressure level, however, decreases less than would be expected. As energy is absorbed, the loudspeakers begin to operate more efficiently, which tends to hold the sound pressure level constant. It was observed that a 75-cubic-foot test specimen with 25 square feet of an acoustical noise absorbing material exposed caused the average sound pressure level in the chamber to drop only 4 db.

Applications

In the large reverberant chamber, complete operational systems have been subjected to acoustic noise environments that simulated the powered flight phase of an ICBM missile. The systems were mounted on the actual internal structure of the missile for the tests, and the structure was suspended on bungee cord in the chamber. The systems, which included relays, pressure and acceleration sensitive transducers, power supplies, oscillators, and transmitters, were operated and monitored during the acoustic tests. The results of these tests proved that the systems would operate within specification requirements during acoustic noise environments and that the systems were not permanently affected by the environment.

We not only use the large reverberant chamber to satisfy acoustic environmental requirements, but also to determine noise attenuation through complete vehicles that are subjected to noise environments. Microphones mounted externally and internally to the test specimen will provide information on the over-all sound pressure attenuation, and on the attenuation in each frequency band. A structure recently tested had a 30-db attenuation through the external structure. This structure will be subjeced to extremely high adiabatic wall temperatures during flight; therefore, there was a thermal insulation blanket attached internally to the structure that provided most of the attenuation. Even with this attenuation, there were significant vibration levels on the internal structure where most of the components were mounted.

Conclusions

All vibration environmental conditions expected during the life of a missile must be simulated in the laboratory. Since the exact causes of failure due to acoustic noise environments are not well established and the amount of energy transmitted to each mass of even the smallest component cannot be determined, it is extremely important that acoustic noise tests as well as mechanical vibration tests be performed in the laboratory prior to the flight of a missile.

The facility described in this article, when used in conjunction with power amplifiers in a vibration and acoustic noise test system, is a practical and economical method of providing adequate mechanical and acoustic testing capabilities to simulate acoustic noise and vibration environments of most missile systems. END

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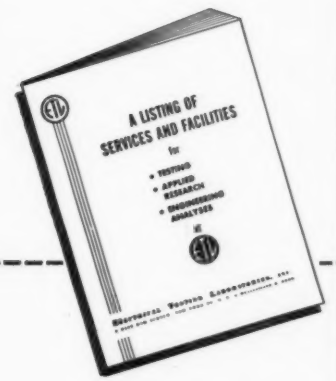

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